CITY OF MT. SHASTA
GENERAL PLAN

DECEMBER 16, 1992

APPENDIX
to the
FINAL GENERAL PLAN
AND
FINAL
ENVIRONMENTAL IMPACT REPORT

Before the Mt. Shasta City Council
December 16, 1992

City of Mt. Shasta
305 North Mt. Shasta Boulevard
Mt. Shasta, California 96067
916 - 926 - 3464

EXISTING NOISE ENVIRONMENT

General

The State Office of Planning and Research Noise Element Guidelines require that major noise sources be identified and quantified by preparing generalized noise contours for current and projected conditions. Significant noise sources include traffic on major roadways and highways, railroad operations, airports, and representative industrial activities and fixed noise sources.

Noise modeling techniques and noise measurements were used to develop generalized L_{dn}[1] noise contours for the major roadways, railroads and fixed noise sources in the City of Mount Shasta General Plan study area for existing conditions.

Noise modeling techniques use source-specific data including average levels of activity, hours of operation, seasonal fluctuations, and average levels of noise from source operations. Modeling methods have been developed for a number of environmental noise sources including roadways, railroad line operations and industrial plants. Such methods produce reliable results as long as data inputs and assumptions are valid. The modeling methods used in this report closely follow recommendations made by the State Office of Noise Control, and were supplemented where appropriate by field-measured noise level data to account for local conditions. The noise exposure contours are based upon annual average conditions. Because local topography, vegetation or intervening structures may significantly affect noise exposure at a particular location, the noise contours should not be considered site-specific.

A community noise survey was conducted to describe existing noise levels in noise-sensitive areas within the City of Mount Shasta General Plan study area so that noise level performance standards could be developed to maintain an acceptable noise environment.

Roadways

The Federal Highway Administration (FHWA) Highway Traffic Noise Prediction Model (FHWA-RD-77-108) was used to develop L_{dn} contours for all highways and major arterial roadways in the City of Mount Shasta General Plan study area. The FHWA Model is the analytical method presently favored for traffic noise prediction by most state and local

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1. For an explanation of terms used in this report, see Appendix A.

agencies, including Caltrans. The current version of the model is based upon the CALVENO noise emission factors for automobiles, medium trucks, and heavy trucks, with consideration given to vehicle volume, speed, roadway configuration, distance to the receiver and the acoustical characteristics of the site. The FHWA Model predicts hourly L_{eq} values for free-flowing traffic conditions, and is generally considered to be accurate within 1.5 dB. To predict L_{dn} values, it is necessary to determine the hourly distribution of traffic for a typical 24-hour day and to adjust the traffic volume input data to yield an equivalent hourly traffic volume.

Traffic data representing annual average traffic volumes for existing and future conditions were obtained from Caltrans and City of Mount Shasta General Plan traffic consultant as summarized in Appendix B. Day/night traffic distribution and truck mix data were based upon Caltrans and BBA file data. Using these data and the FHWA methodology, traffic noise levels as defined by L_{dn} were calculated for existing and future traffic volumes. Distances from the centerlines of selected roadways to the 60 and 65 dB L_{dn} contours are summarized in Table I. Figure 1 shows the locations of the 60 dB L_{dn} future roadway noise contours.

In some cases, the actual distances to noise level contours may vary from the distances predicted by the FHWA model. Factors such as roadway curvature, roadway grade, shielding from local topography or structures, elevated roadways, or depressed receivers may affect actual sound propagation. Therefore the distances reported in Table I are estimates of noise exposure along roadways in the City of Mount Shasta. The effects of topography and depressed roadways on roadway noise propagation are discussed later in this report.

TABLE I
NOISE CONTOUR DATA
DISTANCE (FEET) FROM CENTER OF ROADWAY
TO L_{dn} CONTOURS

Seg. No.	Description	Existing		Future	
		60 dB	65 dB	60 dB	65 dB
Interstate 5:					
1	South of S.R. 89	811	376	1372	637
2	S.R. 89 to Lake Street	811	376	1372	637
3	Lake Street to N. Mt. Shasta Interchange	811	376	1372	637
4	N. Mt. Shasta Interchange to Abrams Lake Rd.	939	436	1588	737
5	North of Abrams Lake Road	939	436	1588	737
State Route 89:					
6	South of I-5	179	83	323	150
West Lake Street:					
7	West of Morgan Way	72	33	98	46
8	Morgan Way to Commercial Street	72	33	98	46
9	Commercial Street to Pine	78	36	106	49
10	East of Pine	78	36	106	49
Mount Shasta Boulevard					
11	S.R. 89 to Wayside Inn	19	9	27	12
12	Wayside Inn to Ream Street	80	37	110	51
13	Ream Street to Chestnut	91	42	124	58
14	Chestnut to Mt. Shasta Park	57	27	78	36
15	North of Mt. Shasta Park	43	20	59	28

The effects of factors such as depressed roadway, grade, etc. can be determined from site-specific traffic noise measurements. The noise measurement results can be compared to the FHWA model results by entering the observed traffic volumes, speed and distance as inputs to the FHWA model. The differences between the measured and predicted noise levels can be used to adjust the FHWA model and more precisely determine the locations of the traffic noise contours. Table II provides some examples of roadway noise calibration results along major highways within the City of Mount Shasta, some of which differ from the FHWA Model prediction results. Figure 2 shows the locations of the noise monitoring sites.

TABLE II
EXAMPLE ROADWAY NOISE PREDICTIONS
(Measurements vs. FHWA Model Results)

Roadway Segment	Vehicles/hour			Distance (feet)	L_{eq}, dB		Reason for Difference
	Autos	Med. Trucks	Hvy. Trucks		Measured	Modeled	
S.R. 49 S. of I-5	168	12	48	50	68.1	68.0	No Difference
I-5 S. of Lake Dr.	800	12	280	150	61.7	69.0	Depressed Roadway
I-5 @ Ivy Street	1168	32	240	300	60.4	64.6	Depressed Roadway in So. Bound Direction
I-5 @ Mt. Shasta Hospital	1280	40	264	250	60.5	66.2	Depressed Roadway

The differences between the roadway noise measurements and the FHWA model prediction results shown above are site specific. They are provided to illustrate the potential effects that local topography, roadway grade and elevated receivers can have on noise propagation.

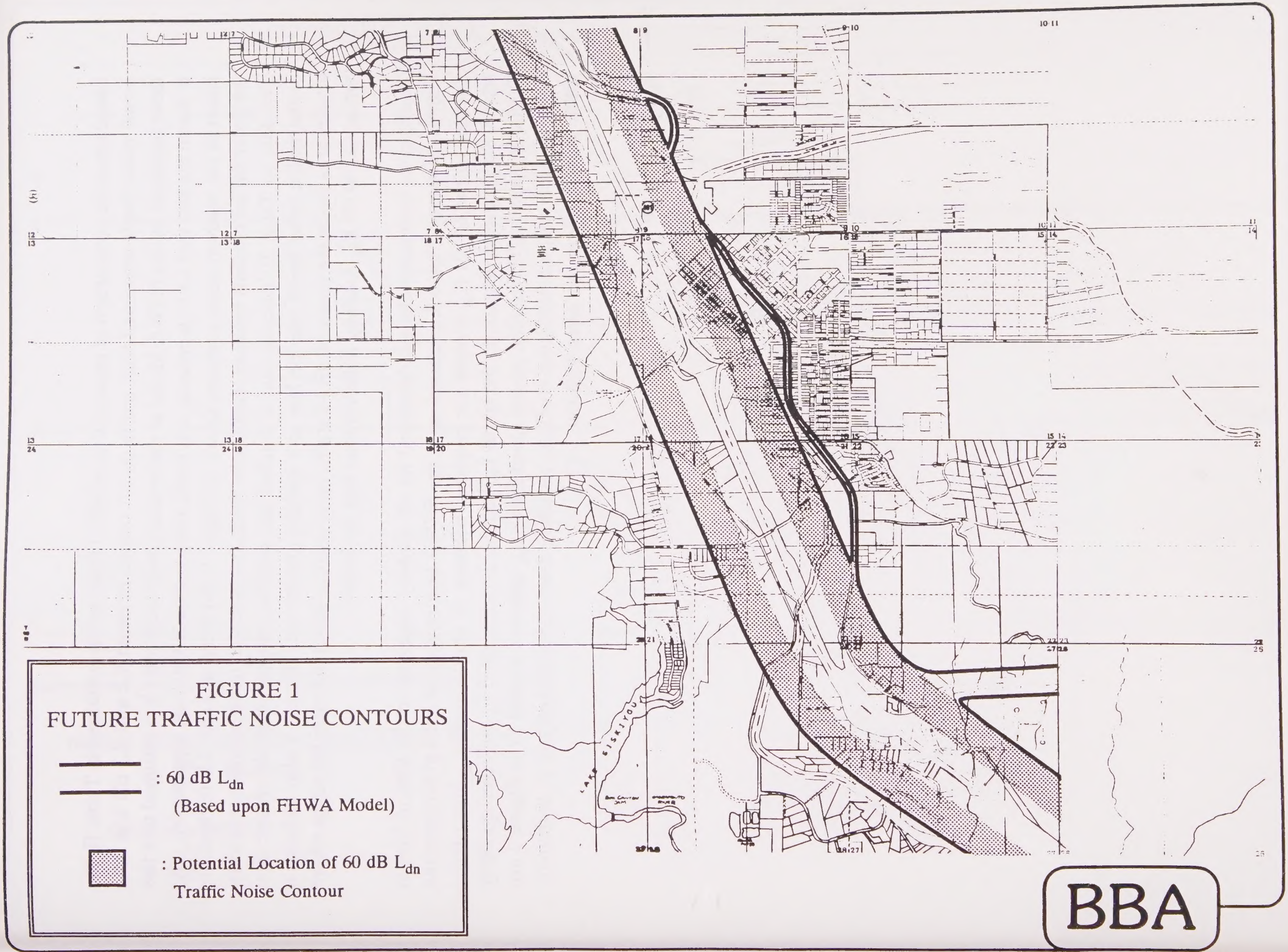


FIGURE 1
FUTURE TRAFFIC NOISE CONTOURS

: 60 dB L_{dn}
(Based upon FHWA Model)

: Potential Location of 60 dB L_{dn}
Traffic Noise Contour

Based upon the comparison of measured vs modeled noise levels contained in Table II, the actual noise levels associated with traffic on I-5 ranged between 4.2 and 7.3 dB less than those predicted by the FHWA Model at the measurement locations. It is assumed that this is due to the fact that I-5 is depressed, and traffic noise is shielded by local topography. The intent of the roadway noise contours shown on Figure 1 and listed in Table I is to illustrate the potential for conflicts between traffic noise levels and potential noise-sensitive receivers. The data in Table II indicates that a detailed site-specific analysis could determine that actual traffic noise levels may be less at a specific project site. Figure 1 also includes a shaded area inside the future 60 dB I-5 traffic noise contour which indicates the range where the actual 60 dB L_{dn} roadway noise contour may be located.

Traffic noise contours were not developed for all roadway segments in the City of Mount Shasta. However, Figure 3, prepared using the FHWA Model, may be used to estimate the distance to the 60 dB L_{dn} contour for projected volumes of arterial traffic. For arterial traffic, the predicted distance to the 60 dB L_{dn} contour is determined by the Average Daily Traffic Volume (ADT) and the posted speed limit. L_{dn} contours derived from Figure 3 are only indicators of potential noise conflicts, requiring more detailed analysis to determine traffic noise levels at any given location.

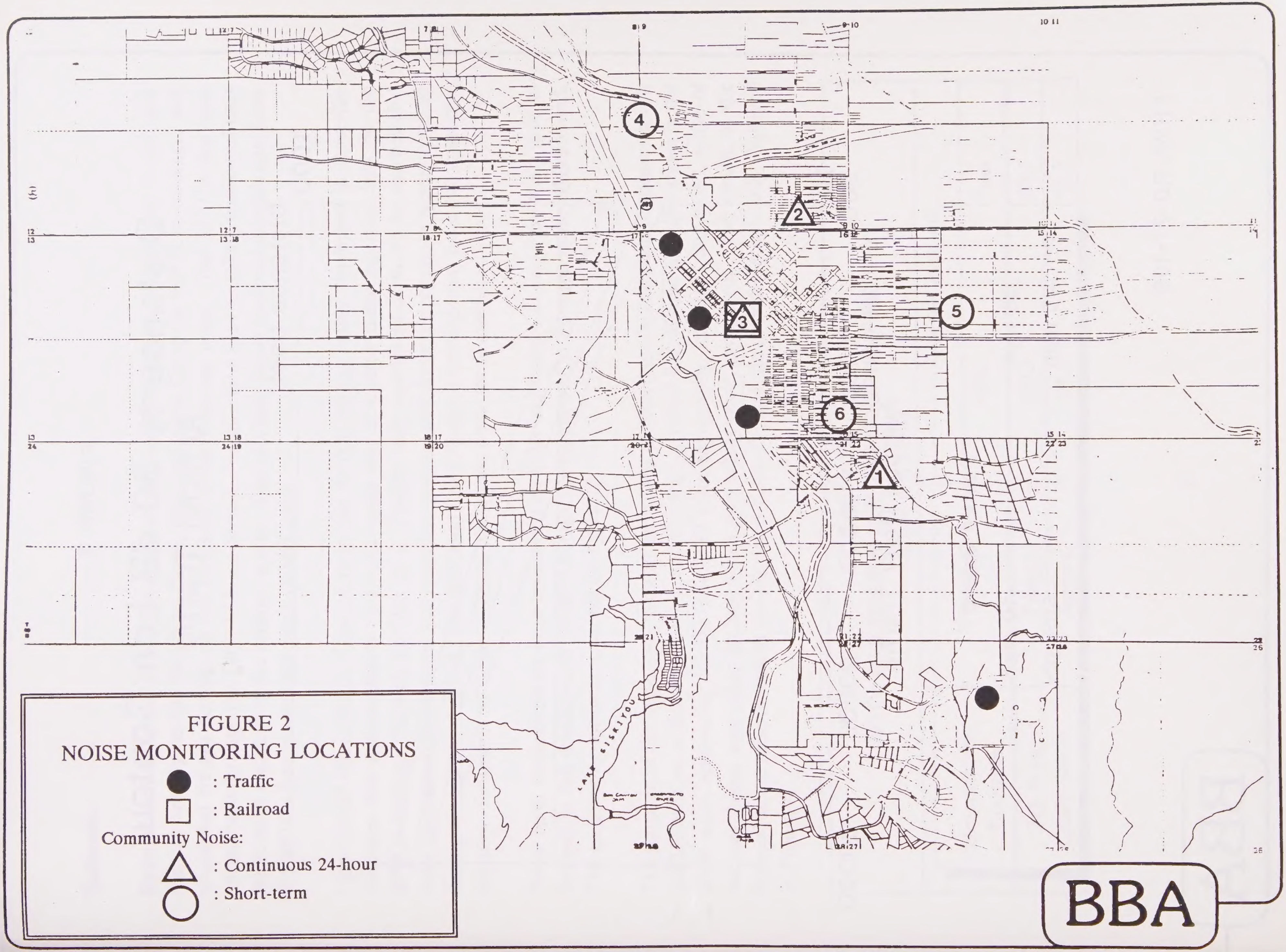
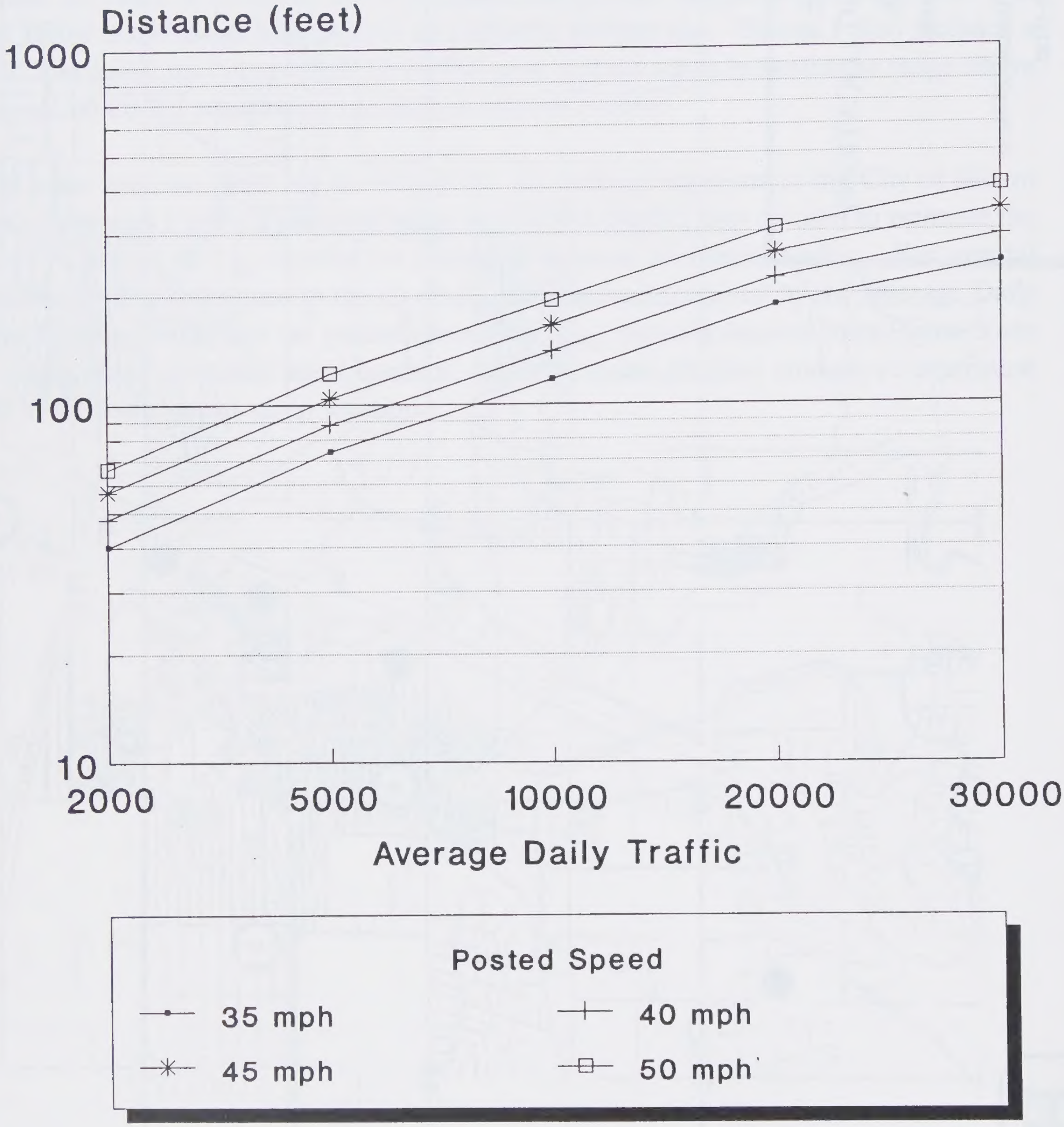


FIGURE 2
NOISE MONITORING LOCATIONS

FIGURE 3

Distance to 60 dB Ldn Contour

Arterial Traffic



FHWA RD-77-108

BBA

Railroads

Railroad activity in the City of Mount Shasta General Plan study area includes freight and Amtrak activity on the Southern Pacific Transportation Company (SPTCo) trackage, and occasional freight activity on the McCloud River Railroad track. The SPTCo line runs north/south through the City of Mount Shasta. Various land uses including residential uses are located adjacent to the railroad tracks. The McCloud River Railroad extends east from the SPTCo line toward the town of McCloud.

Operational information obtained from the SPTCo North Trains dispatcher in Roseville indicates that approximately 16 freight trains and 2 Amtrak trains operate daily on the SPTCo trackage through the plan area. Freight train operations occur on an unscheduled basis throughout the daytime and nighttime periods, and Amtrak operations generally occur during the nighttime period. The McCloud River Railroad trackage may have one operation per day. Estimates of future railroad operations were not available.

Noise level measurements were conducted by BBA within the General Plan study area to determine the contribution of SPTCo railroad operations to the area noise environment. The monitoring location is shown on Figure 2.

The purpose of the noise level measurements was to determine typical sound exposure levels (SEL), number of daily operations, and existing L_{dn} values for railroad line operations in the study area, accounting for the effects of local topography, climate, train speed, noise of warning horns and other factors which may affect noise generation. The results of the railroad noise measurements are shown in Table IV, and the data are graphically displayed in Figure 4.

TABLE IV
SPTCo RAILROAD NOISE MEASUREMENT RESULTS
(June 8-9, 1992)

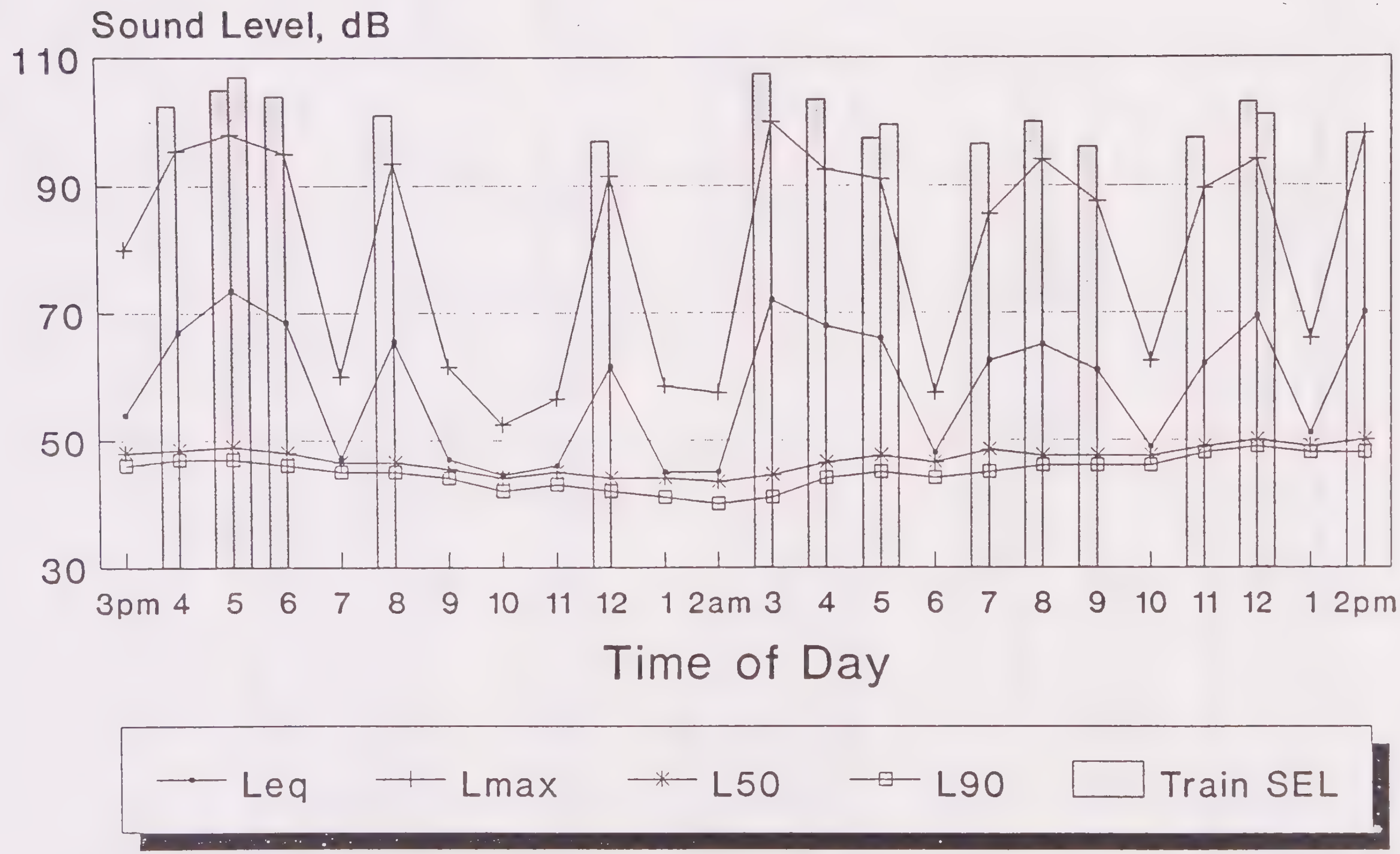
Measurement Location	Train type	Noise Level, dB	
		SEL	L_{max}
215 West Castle Street	Freight	103.2	93.2
	Amtrak	96.5	91.3

FIGURE 4

Hourly/Train Operation Noise Levels

215 W. Castle St.

June 8-9, 1992



Ldn = 71.5 dB

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Based upon field observations, the major noise sources associated with train operations in Mount Shasta are warning horn and locomotive engines. There are approximately 5 at-grade railroad crossings within the City of Mount Shasta, and warning horns can be sounded and heard at almost any location along the SPTCo trackage.

To determine the distance to the 60 and 65 dB railroad L_{dn} contours, it was necessary to calculate the L_{dn} for typical freight and passenger train operations. This was done using the SEL data collected during the railroad noise measurements and the above-described number and distribution of daily freight and passenger train operations.

The L_{dn} contribution may be calculated as follows:

$$L_{dn} = \overline{SEL} + 10 \log N_{eq} - 49.4 \text{ dB, where:}$$

$\overline{SEL}$ is the mean SEL of the event, N_{eq} is the sum of the number of daytime events (7 a.m. to 10 p.m.) per day plus ten times the number of nighttime events (10 p.m. to 7 a.m.) per day, and 49.4 is ten times the logarithm of the number of seconds per day.

For the purposes of the General Plan Noise Element, it is useful to estimate generalized distances to the 60 and 65 dB L_{dn} noise contours for each of the railroad tracks within the City of Mount Shasta. Table V shows the generalized distances to the noise contours associated with railroad operations within the City of Mount Shasta. Figure 5 shows the locations of the 65 dB L_{dn} railroad noise contours.

TABLE V

APPROXIMATE DISTANCE TO RAILROAD NOISE CONTOURS

Train	L_{dn}, dB, 100 Feet From Tracks	Distance to L_{dn} Contour (feet)	
		60 dB	65 dB
SPTCo	70.7	517	240
McCloud River	51.9	30	14

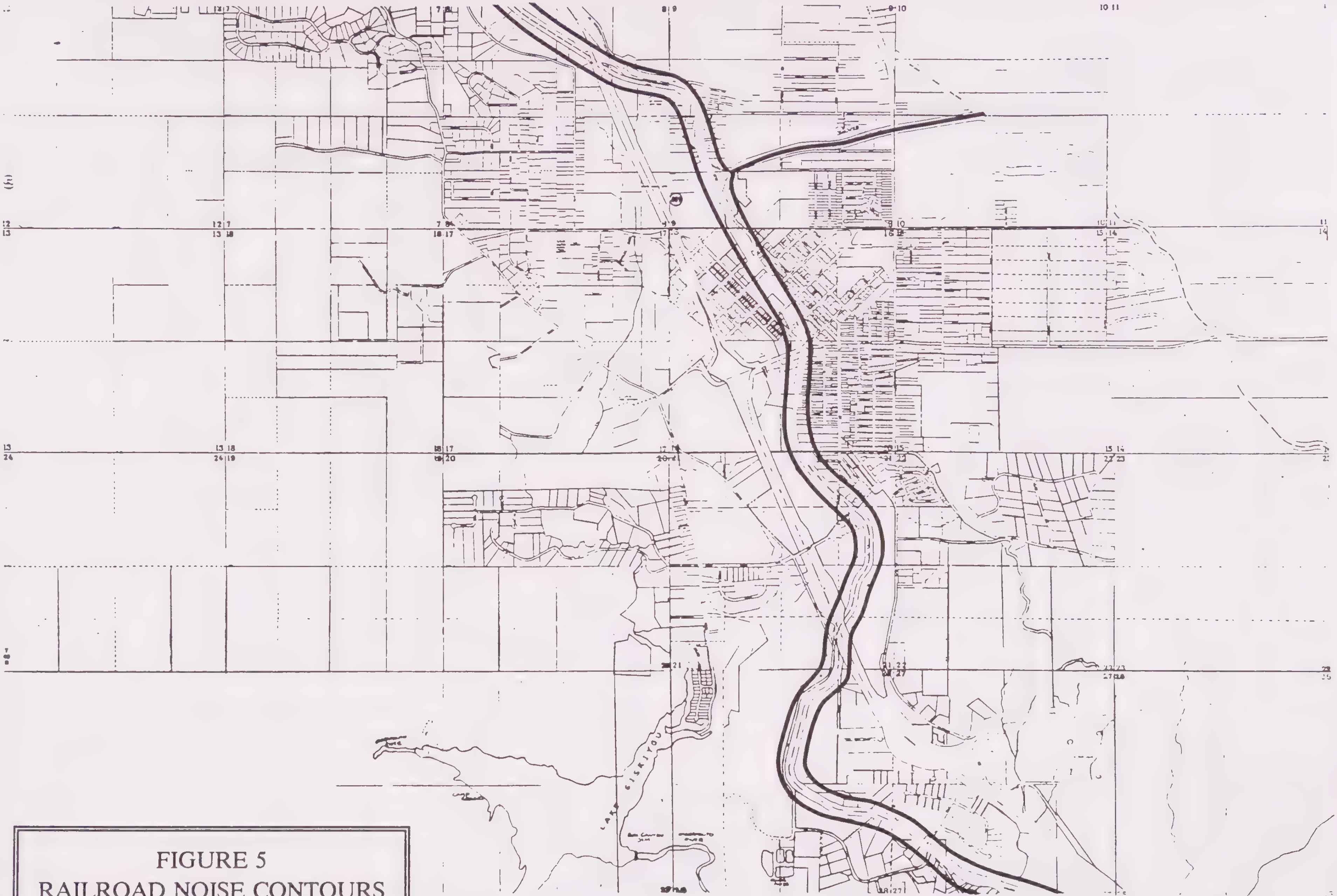

FIGURE 5
RAILROAD NOISE CONTOURS

: 65 dB L_{dn}

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Fixed Noise Sources

The production of noise is a result of many industrial processes, even when the best available noise control technology is applied. Noise exposures within industrial facilities are controlled by Federal and State employee health and safety regulations (OSHA and Cal-OSHA), but exterior noise levels may exceed locally acceptable standards. Commercial, recreational and public service facility activities can also produce noise which affects adjacent sensitive land uses. These noise sources can be continuous and may contain tonal components which may be annoying to individuals who live in the nearby vicinity. In addition, noise generation from fixed noise sources may vary based upon climatic conditions, time of day and existing ambient noise levels.

From a land use planning perspective, fixed-source noise control issues focus upon two goals: to prevent the introduction of new noise-producing uses in noise-sensitive areas, and to prevent encroachment of noise sensitive uses upon existing noise-producing facilities. The first goal can be achieved by applying noise performance standards to proposed new noise-producing uses. The second goal can be met by requiring that new noise-sensitive uses in proximity to noise-producing facilities include mitigation measures to ensure compliance with noise performance standards.

There are numerous industrial facilities which are dispersed throughout the General Plan Study Area. The following descriptions of existing fixed noise sources in the City of Mount Shasta General Plan study area are intended to be representative of the relative noise impacts of such uses, and to identify specific noise sources which should be considered in the review of development proposals.

There are three areas within the City of Mount Shasta which have light industry and commercial uses. The three areas include the north side of town, adjacent to Mount Shasta Boulevard, between the Mount Shasta Park and Nixon Street; the south Ream Avenue area which is located near the intersection of Ream Avenue and Court Street; and the south side area adjacent to Mount Shasta Boulevard. In addition, the Sousa Redi-Mix facility which is located outside of the City limits in Siskiyou County was identified as a potential fixed noise source affecting areas within the Mount Shasta city limits.

<u>North Side Commercial Area</u>:

The commercial area on the north side of Mount Shasta is comprised primarily of commercial land uses which include petroleum product sales, automotive repair, and tire and

automotive supply. Typical noise sources associated with these land uses include heavy truck traffic, HVAC systems, tire breakers, impact wrenches and compressors.

The majority of the businesses in this area operate during the daytime hours. During a site investigation on June 9, 1992, the noise environment in this area was dominated by local roadway traffic and railroad activities. Noise measurements associated with the operation of the businesses were not conducted. However, BBA file data for typical single event noise levels associated with truck movements range between 70 and 85 dB SEL at a distance of 75 feet. BBA file data for maximum noise levels associated with air impact wrenches and tire breakers are approximately 89 dB and 105 dB respectively, at a distance of 10 feet.

Discussions with City staff indicate that commercial operations in this area do not generate many noise complaints from nearby residences.

South Ream Avenue Area:

The south Ream Avenue area is comprised primarily of trucking facilities. Noise sources associated with the operation of these facilities include truck traffic, HVAC systems and refrigeration trucks. These facilities typically operate during the daytime hours. However, the refrigeration trucks have compressors which may operate 24 hours per day.

Based upon discussions with the City staff, the refrigeration trucks frequently generate noise complaints from residents adjacent to the facilities. BBA conducted sound level measurements of two refrigeration trailer compressors which were operating on June 9, 1992, at one of the trucking facilities. A continuous noise level of 64 dB was measured at a distance of 50 feet from the trailers.

South Commercial/Industrial Area:

This area includes an abandoned lumber yard, the City of Mount Shasta Public Works Yard and the Siskiyou Opportunity Center, which includes a recycling center.

Noise sources associated with the City's Public Works yard are primarily related to the movement of heavy equipment. However, these activities are intermittent and seldom occur.

The recycling center which is associated with the Siskiyou Opportunity Center is located at the corner of Mount Shasta Boulevard and Bear Springs Road. The recycling center operates between the hours of 8:00 a.m. and 3:30 p.m. Monday through Friday, and 9:00

a.m. to 3:30 p.m. every other Saturday. Major noise sources associated with the operation of the recycling center include breaking glass and a can crushing machine, which crushes aluminum cans and loads the cans into transport trucks.

Recently, the City of Mount Shasta received a noise complaint with regards to the operation of the recycling center. At the request of the City, the operator constructed a building which currently houses the "glasshopper" and provides some shielding of noise levels from the can crushing operation. BBA conducted noise level measurements of the can crusher operation on June 9, 1992. The noise level associated with the operation of the can crusher was 80 dB L_{eq} at a distance of 50 feet. The noise measurement location did not benefit from shielding.

Sousa Redi-Mix:

The Sousa Redi-Mix plant is located at 100 Upton Road, outside of the city limits on the west side of Interstate 5. Sousa Redi-Mix provides sand and gravel and redi-mix products. Typical noise sources associated with the plant operation which could be heard within the city limits could include truck traffic, front loaders, back up bells, conveyor belt systems, air vibrators which shake material from hoppers into trucks, and the sound of sand and gravel on metal as trucks are being loaded.

During a site visit on June 9, 1992, the noise environment within the city limits was dominated by roadway traffic on I-5, and operations associated with the redi-mix plant did not contribute significantly to the area noise environment.

Community Noise Survey

A community noise survey was conducted to document noise exposure in areas of the city containing noise sensitive land uses. For that purpose, noise sensitive land uses in the City of Mount Shasta General Plan study area were considered to include residential areas, parks and schools. Noise monitoring sites were selected to be representative of typical conditions in the city.

Short-term noise monitoring was conducted on June 8-9, 1992 at three separate sites. Each site was monitored three different times during the day and night so that valid estimates of L_{dn} could be prepared. Three long-term noise monitoring sites were established in the City as part of the General Plan Update to record day-night statistical noise level trends. The data collected included the L_{eq} and other statistical descriptors. Measured noise levels and

estimated L_{dn} values at each site are summarized in Table VI. Monitoring sites are shown by Figure 2. Figures 6-8 show the results of the community noise monitoring.

Community noise monitoring systems were calibrated with acoustical calibrators in the field prior to use. The systems comply with all pertinent requirements of the American National Standards Institute (ANSI) for Type I sound level meters.

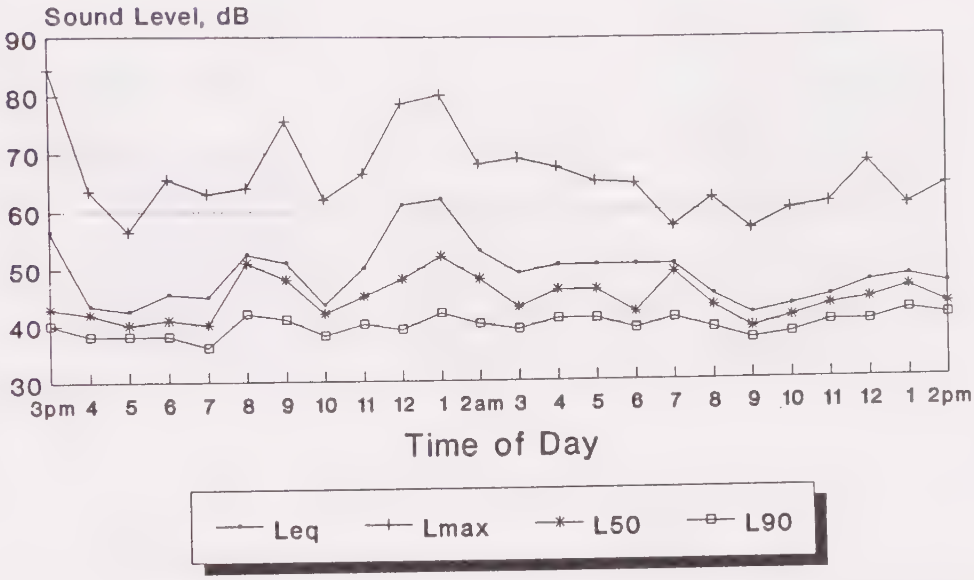
The community noise survey results indicate that typical noise levels in noise sensitive areas of the City of Mount Shasta General Plan study area are in the range of 46 dB to 71 dB L_{dn}. Traffic on I-5, local roadways, railroad line operations and neighborhood activities are the controlling factors for background noise levels in the majority of the study area.

The L_{90} values shown in Figures 6 and 7 for the 24-hour monitoring locations represent background noise levels, where there are typically no identifiable local noise sources. The L_{50} values represent median noise levels. The L_{eq} values in Table VI and Figures 6 through 8 represent the average noise energy during the sample periods, and show the effects of brief noisy periods. The L_{eq} values were the basis of the estimated L_{dn} values. L_{max} values show the maximum noise levels observed during the samples.

The noise levels measured at 215 Castle Street (Figure 7) indicate that most of the hourly L_{eq} values were influenced by train traffic along the SPTCo tracks.

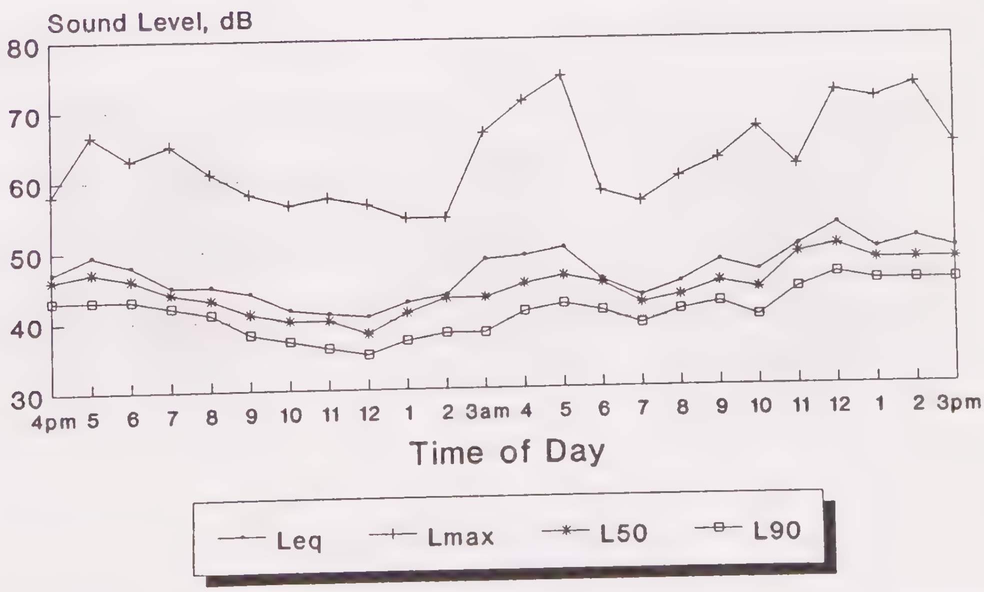
FIGURE 6

Hourly Noise Levels
509 Le Baron St.
June 8-9, 1992



Ldn = 61.9 dB

Hourly Noise Levels
619 Ski Bowl Dr.
June 8-9, 1992



Ldn = 52.9 dB

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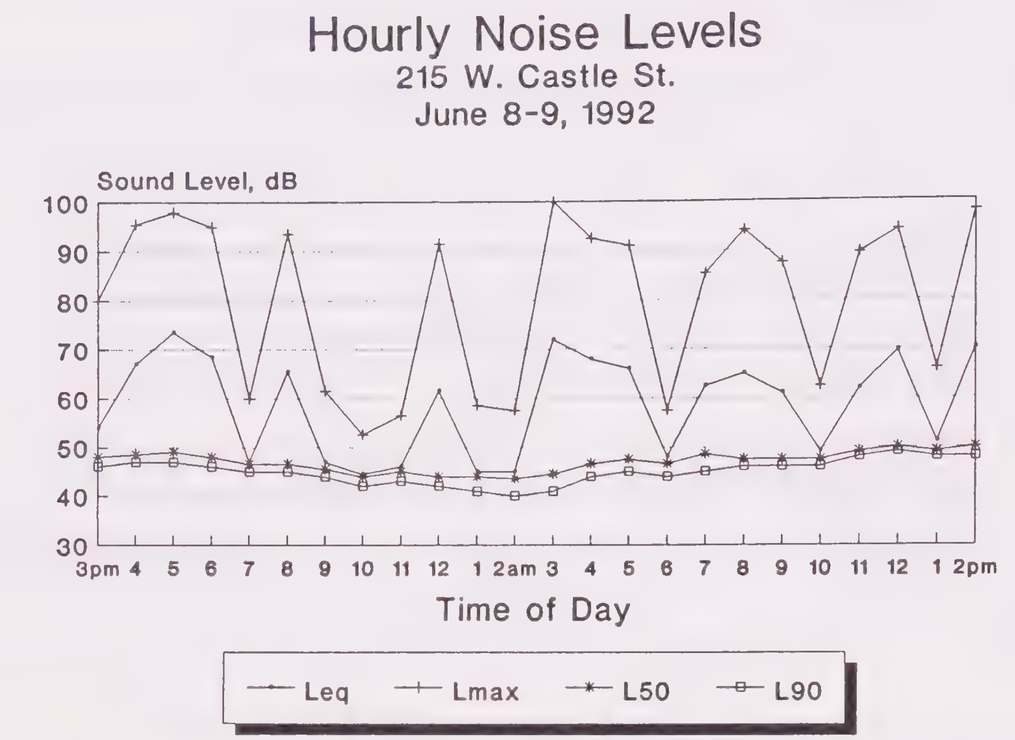
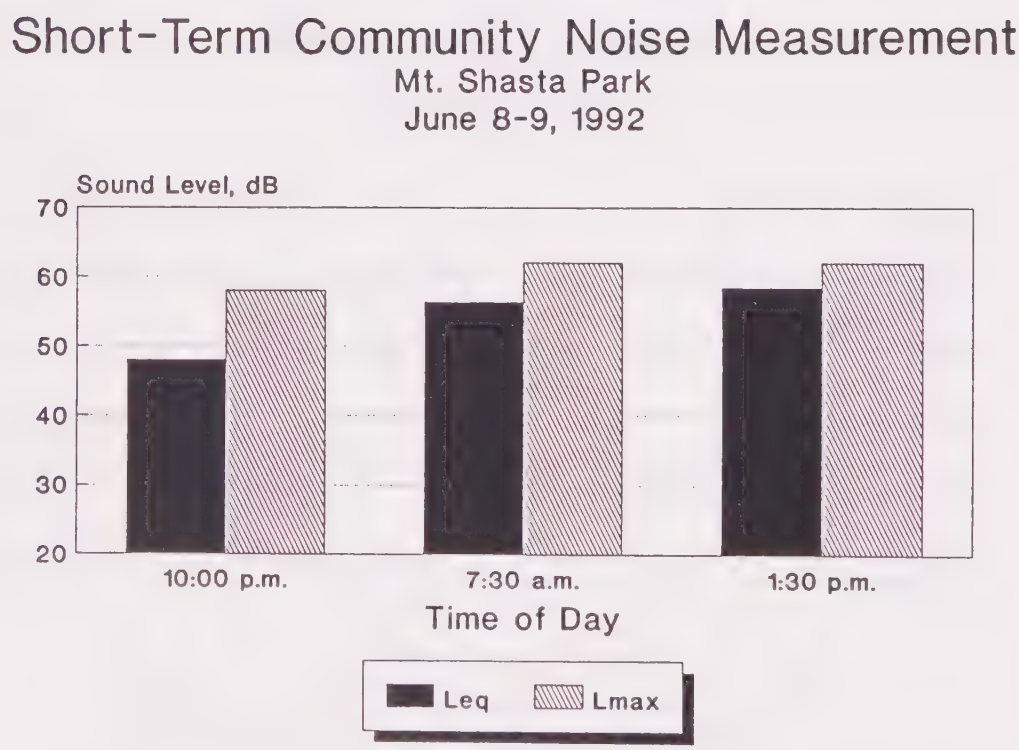
FIGURE 7



Ldn = 71.5 dB



Ldn = 58 dB

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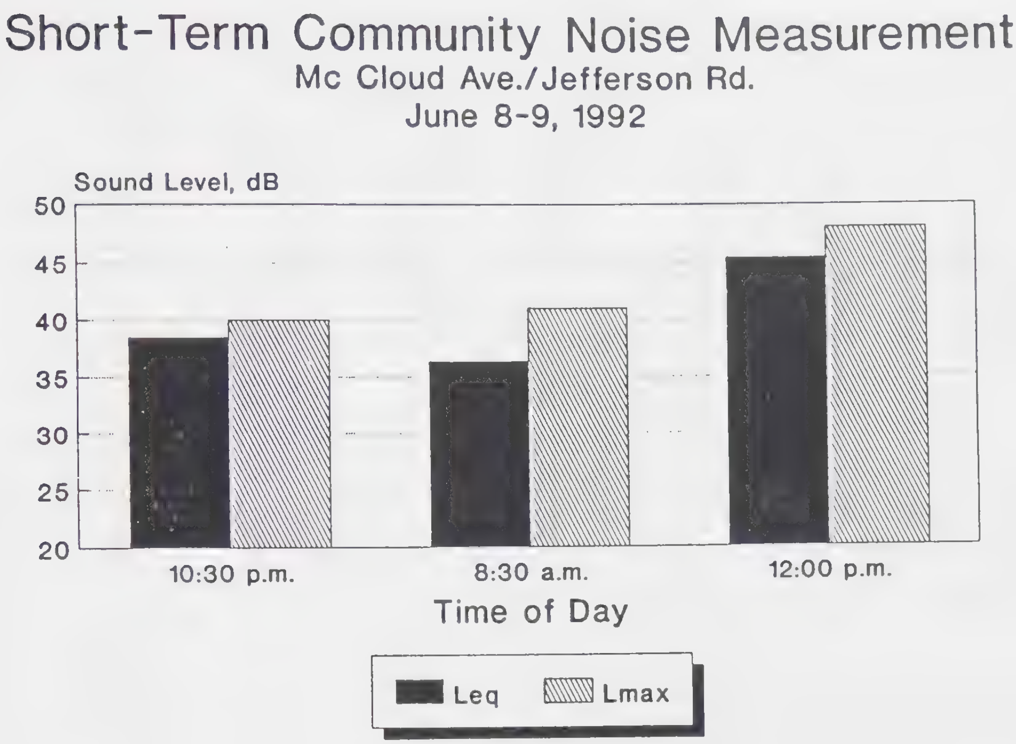
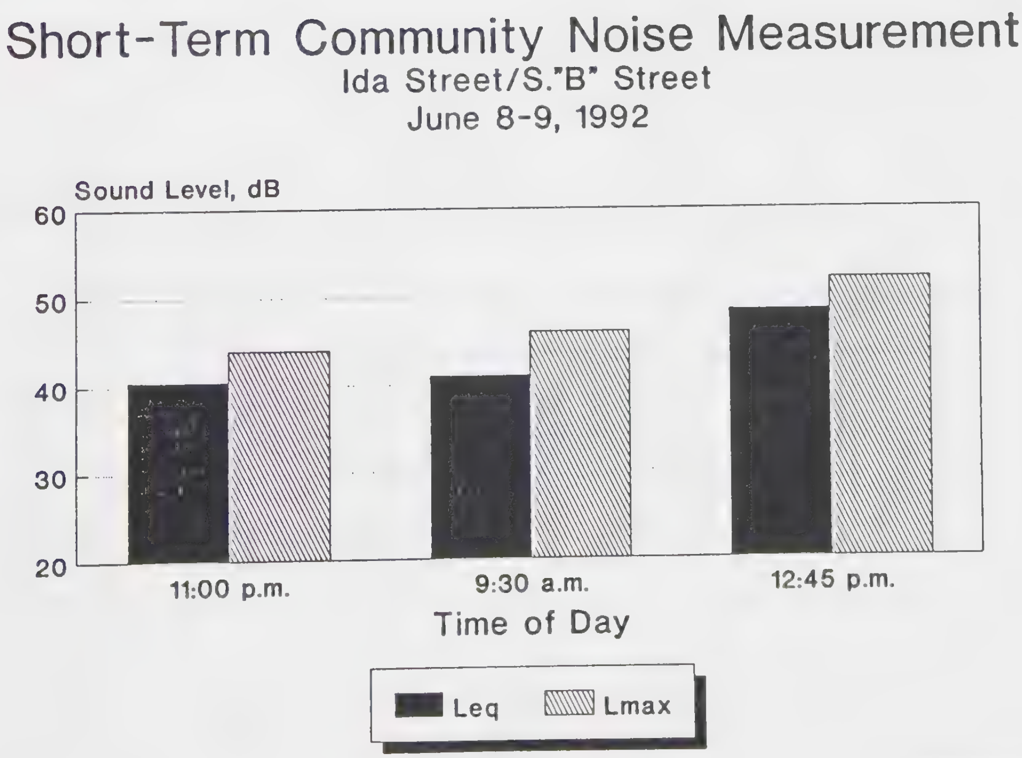
FIGURE 8



Ldn = 46 dB



Ldn = 48 dB

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TABLE VI

SUMMARY OF MEASURED NOISE LEVELS AND ESTIMATED DAY-NIGHT AVERAGE LEVELS (L_{dn}) IN AREAS CONTAINING NOISE SENSITIVE LAND USES

Site	Location	Date	Time	Sound Level, dB				
				L_{90}	L_{50}	L_{eq}	L_{max}	Est. L_{dn}
*1	509 LeBaron Street	6/8/92	17:00	38	40	42.5	56.5	
		6/8/92	23:00	40	45	50.0	66.5	
		6/9/92	10:00	38	41	43.0	60.0	61.9 dB
*2	619 Ski Bowl Drive	6/8/92	17:00	43	47	49.5	66.5	
		6/8/92	23:00	36	40	41.0	57.5	
		6/9/92	10:00	40	44	46.5	67.0	52.9 dB
*3	215 West Castle Street	6/8/92	17:00	47	48	73.5	98.0	
		6/8/92	23:00	43	45	46.0	56.5	
		6/9/92	10:00	46	48	49.0	62.5	71.5 dB
4	Mount Shasta Park	6/8/92	22:00	--	--	48.0	58.0	
		6/9/92	7:00	--	--	56.3	62.0	
		6/9/92	13:30	--	--	58.5	62.0	58.0 dB
5	McCloud Avenue/Jefferson Road	6/8/92	22:30	--	--	38.5	40.0	
		6/9/92	8:30	--	--	36.3	41.0	
		6/9/92	12:00	--	--	45.4	48.0	46.0 dB
6	Ida Street/So. "B" Street	6/8/92	23:00	--	--	40.5	44.0	
		6/9/92	9:30	--	--	41.0	46.0	
		6/9/92	12:45	--	--	48.4	52.0	48.0 dB

* = Continuous monitoring site

APPENDIX A
ACOUSTICAL TERMINOLOGY

AMBIENT NOISE LEVEL: The composite of noise from all sources near and far. In this context, the ambient noise level constitutes the normal or existing level of environmental noise a given location.

CNEL: Community Noise Equivalent Level. The average equivalent sound level during a 24-hour day, obtained after addition of approximately five decibels to sound levels in the evening from 7:00 p.m. to 10:00 p.m. and ten decibels to sound levels in the night before 7:00 a.m. and after 10:00 p.m.

DECIBEL, dB: A unit for describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the reference pressure, which is 20 micropascals (20 micronewtons per square meter).

L_{dn}: Day-Night Average Sound Level. The average equivalent sound level during a 24-hour day, obtained after addition of ten decibels to sound levels in the night after 10:00 p.m. and before 7:00 a.m.

L_{eq}: Equivalent Sound Level. The sound level containing the same total energy as a time varying signal over a given sample period. L_{eq} is typically computed over 1, 8 and 24-hour sample periods.

Note: CNEL and L_{dn} represent daily levels of noise exposure averaged on an annual basis, while L_{eq} represents the average noise exposure for a shorter time period, typically one hour.

L_{max}: The maximum sound level recorded during a noise event.

L_n: The sound level exceeded "n" percent of the time during a sample interval. L_{10} equals the level exceeded 10 percent of the time (L_{90}, L_{50}, etc.)

ACOUSTICAL TERMINOLOGY

NOISE EXPOSURE CONTOURS: Lines drawn about a noise source indicating constant levels of noise exposure. CNEL and L_{dn} contours are frequently utilized to describe community exposure to noise.

SEL OR SENEL: Sound Exposure Level or Single Event Noise Exposure Level. The level of noise accumulated during a single noise event, such as an aircraft overflight, with reference to a duration of one second. More specifically, it is the time-integrated A-weighted squared sound pressure level for a stated time interval or event, based on a reference pressure of 20 micropascals and a reference duration of one second.

SOUND LEVEL: The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the response of the human ear and gives good correlation with subjective reactions to noise.

APPENDIX B-1

FHWA Model RD-77-108: Brown-Buntin Associates, Inc.
Calveno Emission Curves   Run Date: 06-18-1992
Project Number: 92-274   Run Time: 08:47:28
Year: Existing
Soft Site

INPUT DATA SUMMARY:

Segment	ADT	Day%	Eve%	Nite%	%MT	%HT	Speed	Distance	Offset
1	18500	86.0	0.0	14.0	5.0	23.9	65.0	100.0	0.0
2	18500	86.0	0.0	14.0	5.0	23.9	65.0	100.0	0.0
3	18500	86.0	0.0	14.0	5.0	23.9	65.0	100.0	0.0
4	21700	86.0	0.0	14.0	6.0	25.9	65.0	100.0	0.0
5	21700	86.0	0.0	14.0	6.0	25.9	65.0	100.0	0.0
6	3450	85.0	0.0	15.0	4.0	13.1	55.0	100.0	0.0
7	8400	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
8	8400	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
9	9500	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
10	9500	87.0	0.0	13.0	2.0	2.0	35.0	100.0	0.0
11	750	87.0	0.0	13.0	2.0	2.0	30.0	100.0	0.0
12	7300	87.0	0.0	13.0	2.0	2.0	30.0	100.0	0.0
13	8800	87.0	0.0	13.0	2.0	2.0	30.0	100.0	0.0
14	6000	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
15	2900	87.0	0.0	13.0	2.0	2.0	30.0	100.0	0.0

APPENDIX B-2

FHWA Model RD-77-108: Brown-Buntin Associates, Inc.
Calveno Emission Curves   Run Date: 06-18-1992
Project Number: 92-274   Run Time: 08:42:57
Year: future
Soft Site

INPUT DATA SUMMARY:

Segment	ADT	Day%	Eve%	Nite%	%MT	%HT	Speed	Distance	Offset
1	40700	86.0	0.0	14.0	5.0	23.9	65.0	100.0	0.0
2	40700	86.0	0.0	14.0	5.0	23.9	65.0	100.0	0.0
3	40700	86.0	0.0	14.0	5.0	23.9	65.0	100.0	0.0
4	47740	86.0	0.0	14.0	6.0	25.9	65.0	100.0	0.0
5	47740	86.0	0.0	14.0	6.0	25.9	65.0	100.0	0.0
6	8332	85.0	0.0	15.0	4.0	13.1	55.0	100.0	0.0
7	13440	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
8	13440	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
9	15200	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
10	15200	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
11	1200	87.0	0.0	13.0	2.0	2.0	35.0	100.0	0.0
12	11680	87.0	0.0	13.0	2.0	2.0	30.0	100.0	0.0
13	14080	87.0	0.0	13.0	2.0	2.0	30.0	100.0	0.0
14	9600	87.0	0.0	13.0	2.0	2.0	25.0	100.0	0.0
15	4640	87.0	0.0	13.0	2.0	2.0	30.0	100.0	0.0

VOLCANIC HAZARDS INFLUENCING THE CITY OF MT. SHASTA

INTRODUCTION

The City of Mount Shasta lies on the southwestern flank of the Mt. Shasta volcano, a large, historically active eruptive center in the southern Cascade Mountains. Mt. Shasta has erupted at least once every 600-800 years for the past 10,000 years and its most recent eruption was 206 years ago in 1786 (Christiansen, 1982). The potential volcanic hazards to the City's "General Plan - Sphere of Influence Area" (See Figure 1) have been detailed in geologic literature, with the most pertinent studies having been completed since the Mount St. Helens eruption in 1980. This report draws heavily from two articles (Miller, 1980; Crandell and Nichols, 1987).

The Mt. Shasta volcano has a long and irregular history of eruption extending back at least 593,000 years (Crandell, 1989, p.3). It is important to remember that volcanic eruption forecasts are not an exact science. However, while the exact date of eruption is not predictable, it is safe to say that Mt. Shasta will erupt again. Many volcanic hazards are lethal and the best way to reduce the risk is to get out of harms way. It will be impossible to remove all risk from volcanic eruptions to the city of Mt. Shasta, yet by careful planning these risks can be minimized.

Prudent planning considerations designed to lessen the risk to the citizenry and properties within the City of Mount Shasta Sphere of Influence are:

1) Long term planning and zoning to discourage building in the most hazardous low lying areas having the highest potential to experience volcanic flows.

2) Evaluate power, telephone, water, sewer, and other utilities; roads, and landing strips for their location and resistance to the effects of various volcanic hazards.

3) Evaluate and upgrade necessary building codes to reduce the potential effects of volcanic induced seismic and airfall hazards.

4) Local, State, and Federal governments should develop contingency plans for a possible volcanic eruption at Mt. Shasta including provisions for emergency communications.

5) Educate the citizenry. Distribute pamphlets on the possible volcanic hazards (such as Crandell and Nichols, 1987). Develop and distribute the long term planning goals and emergency contingency plans for the community.

VOLCANIC HAZARDS

The nature of hazardous phenomena that may accompany an eruption of the Mt. Shasta volcano are classified as follows:

1) Earthquake
2) Airfalls
3) Lava flows
4) Lava domes
5) Pyroclastic flows and lateral blasts
6) Volcanic gases
7) Debris flows
8) Landslides

Earthquakes

Volcanic activity is typically accompanied by earthquakes, produced by the movement of molten rock (magma) below the surface. Usually, volcanic quakes are small to moderate, with Richter Scale magnitudes of less than 5. However, more powerful shakes can occur on volcanoes during large landslide events or when a nearby crustal fault shifts (Scott, 1989, p.20). Damage from such quakes, even moderate size quakes, can be widespread and tends to be most severe in unsupported masonry or brick structures. The most severe shaking tends to concentrate in areas built upon thick, unconsolidated soil or gravel deposits. Less severe shaking can be expected in areas underlain by hard bedrock.

Earthquakes typically precede and accompany volcanic eruptions and give geologists some of the best and earliest information concerning the activity within a volcano. Not all episodes of seismic unrest result in an eruption. Many earthquake swarms simply die out without any volcanic activity, as occurred in 1988 at the Medicine Lake volcano and several times during the 1980's in the Mammoth Mountain region of eastern California. In 1978 and 1981 swarms of small to moderate quakes shook the Stephens Pass and Tennant area, about 20 miles northeast of Mt. Shasta volcano, and produced severe ground cracking. These quakes were unlike typical fault-movement (tectonic) quakes and may have been associated with the injection of magma below this area halfway between Mt. Shasta and the Medicine lake volcanoes (Christiansen, 1982).

The consequences of earthquake vibration hazards can be quite serious and include the following: building collapse; fire; falling objects; gas-line, water-line, and electrical-line breaks; and landslides.

Airfalls

Volcanic airfall deposits (or tephra) are produced in explosive eruptions where the materials are launched into the air in a rising, turbulent, typically hot, eruption cloud mixed with a variety of noxious volcanic gases. Tephra consists of ash, which is sand to dust size, as well as larger fragments, of pumice and pulverized rock. Tephra is commonly the first type of volcanic material ejected in an eruption sequence because magma that first reaches the surface is pressurized with gas producing fragmenting explosions. In comparison to other Cascade volcanoes, such as Mt. Saint Helens, Mt. Shasta has produced little tephra. Only twice in the last 10,000 years have Mt. Shasta's explosive eruptions sent large quantities of ash high into the atmosphere.

Tephra falls out of the eruption column in the downwind direction, heavier and larger materials fall close to the eruption vent and progressively finer materials fall further downwind. The area of distribution depends on the direction and strength of the prevailing wind at the time of eruption. About 90% of the time winds in the Mt. Shasta area are westerlys and would blow tephra to the east of a north-south line drawn through any potential eruption vent (Figure 2). During very explosive eruptions, columns of ash and gas rise commonly to heights of 12 miles, and can rise to 33 miles in the atmosphere (Cas and Wright, 1987, p.130,143). The ash would be distributed downwind in a lobe whose shape would depend on the wind velocity, being more elongate during high velocity winds.

If a tephra-producing eruption occurred similar to the 9600-9700 year old Red Banks eruption (Figure 3), the ash and pumice could blanket the city of Mt. Shasta 10-15 inches deep if the winds were blowing from the northeast (a relatively low probability wind direction).

Tephra fall can severely endanger lives and property. Close to the eruption vent large ballistic particles can destroy by impact. Impact damage by larger rock particles is likely only to occur on the upper slopes of the volcano, within about 6 miles of the vent. Further away, heavy blankets of tephra disrupt transportation, create a night-like darkness (even at midday), and can collapse the roofs of buildings.

It is important to realize that volcanic ash is not light, fluffy material; rather is smelly, abrasive grit that is <u>much</u> heavier than a snowfall of the same thickness, especially if wet, due to mixed-in rain. Fine ash and mixed noxious gases can clog breathing passages or poison people, animals, and water supplies, and do serious damage to machinery. Livestock can be sickened or killed by eating ash contaminated grass or feed. Crops and trees can be stripped of leaves and limbs by heavy, abrasive tephra fall. Hot tephra can cause fires.

Lava Flows

Eruption of lava flows and domes has occurred frequently during the geologic history of Mt. Shasta volcano. Lavas consist of molten rock that is extruded from within the earth to the surface. Lava flows and domes are commonly produced in the later part of an eruption sequence after most of the explosive gas in a magma has already vented to the atmosphere by way of explosive discharges.

Flows vary considerably in form depending on the composition and temperature of the magma. Past flows at Mt. Shasta are either blocky lavas or domes. The block lavas are thick, tongue-shaped lobes and extend up to 5.5 miles from their vent. The Lava Park flow on the northwest flank of Mt. Shasta is a good example of this type of flow. The vents that emit lavas vary in location from the summit of Mt. Shasta to a variety of satellite vents up to 5.5 miles from the summit of Mt. Shasta.

Based on the possible distribution of eruption vents, the traveling distance of flows, and the number of times that a sector of the volcano has been affected by lavas in the geologically-recent past (last 10,000 years), the hazard map for Mt. Shasta lavas is shown in Figure 4. The communities of Mt. Shasta, McCloud, and Weed as well as the routes of Highway 5, 97, and 89 all lie in the area of relatively low lava flow hazard probability. The hazard zone that contains the city of Mt. Shasta possibly could receive a lava flow on the frequency of about once every 10,000 years.

Lava flows move relatively slowly, especially on the gently inclined slopes found low on the flanks of the volcano. A person can typically outwalk a moving lava and thus very few lives are ever lost to lava (there are no historic accounts, for example, of any deaths attributed to lava flows in Hawaii). However, just as the movement of a lava is ponderous, it is also relentless. Lavas will bulldoze, crush, and bury any structures that are in their path. The extreme incandescent heat of an active lava will set fire to most materials as it approaches. Although there have been some questionably successful historic attempts to stop or divert moving lavas in such places as Hawaii, Iceland, and Italy, the characteristically thick, massive lavas that Mt. Shasta produces would most likely be immune to any such attempt.

Lava Domes

Lava domes are large bulbous masses of thick, pasty magma which has such a low fluidity that the erupted material simply piles-up over the vent. Domes have been frequently produced in the eruption history of Mt. Shasta volcano. The summit of Shastina as well as Black Butte are good examples of lava domes. Like the more fluid lava flows they are produced at both central as well as satellite vents. Unlike the more fluid lava flows they typically do not travel much beyond their vent area and thus do not threaten to bury or burn structure, except directly at the eruption vent area.

There are two major hazards associated with lava domes, however, that typically make them hazardous than lava flows. First of all, because lava domes are steep-sided they are typically unstable, especially during their growth phase, at which time they often inflate like a balloon. Commonly, a side of the dome will collapse and produce an avalanche of rock debris, sometimes cold but often extremely hot and mobile. This landslide of hot debris is called a pyroclastic flow and is described in the next section. Additionally, there is a great hazard produced at volcanic domes when gas pressure builds up below or within the dome. The hot volcanic gas can produce an explosion and hurl rocks and ash vertically or laterally (called a lateral blast) up to a distance of many miles. This hazard is also discussed in the next section.

Pyroclastic Flows and Lateral Blasts

Pyroclastic flows are dense mixtures of hot ash, pumice, rock fragments, and gas. They are fluidized by hot gas emitted by the pumice and rock fragments and travel from 30 to 90 miles per hour. Rising above the dense current of debris is a billowing cloud of fine gas and ash. These flows have frequently been erupted from both summit and satellite vents of the Mt. Shasta volcano and are produced by powerful explosive eruptions, often the same early eruptions that produce ashfall deposits. The flows can also be produced by a collapse or explosion at a growing volcanic dome (Figure 5). Although pyroclastic flows do not contain water they flow down channels and spread out over broad areas on the gentle lower slopes of the volcano.

Individual pyroclastic flows have traveled as much as 12 miles from their source on Mt. Shasta Volcano. Black Butte dome produced pyroclastic flows that traveled up to 5.5 miles and covered the area of what is now the western side of the city of Mt. Shasta (Figure 6). Because of their high velocity and momentum these flows can climb obstacles in their paths up to 400 feet high.

Pyroclastic flows are the most hazardous eruptive feature related to volcanoes, accounting for about 65,000 deaths worldwide in the last 1000 years (Tilling, 1989, p.4). Their high velocity and temperature makes these flows extremely dangerous. Pyroclastic flows destroy by impact, burial, incineration, or complete removal of obstacles in their paths. People and animals are burned or asphyxiated by the high temperature gas and ash. The hot ash clouds that rise above the pyroclastic flow will spread out and settle beyond and to the sides of the main pyroclastic stream and will also burn or asphyxiate.

Lateral blasts are very similar to pyroclastic flows and are produced by explosions that are <u>directed</u> nearly horizontally, rather than vertically. The blasts tend to travel faster than pyroclastic flows, are less confined to valleys or channels and can reach great distances. The hazards associated with blasts are

similar to those of pyroclastic flows.

The hazard zones for pyroclastic flows and blasts are shown in Figure 7. The communities of Mt. Shasta, McCloud, and Weed; as well as the routes of Interstate Highway 5, Highway 97, and Highway 89 all lie in the area of moderate risk from a Pyroclastic flow or blast. This ring-shaped zone of moderate hazard should receive a pyroclastic flow about once every 1500 years. The furthest a pyroclastic flow or blast is expected to travel is 18 miles from the summit. It is impossible to predict the area that would be affected, the timing, and the magnitude of the blast. Geologists may be able to make some estimation of the region to be affected by this hazard only after monitoring ground changes and evidence of magma injection in the volcano.

Volcanic Gasses

Volcanic gases are expelled before, during, and after volcanic eruptions. At Mt. Shasta volcano there are two gas vents (fumaroles) near the summit, one with a bubbling, acidic hot spring area. During volcanic eruptions fumarolic activity may increase and perhaps flow in new areas. Volcanic gasses predominantly consist of water vapor, carbon dioxide, as well as sulfurous and chlorine gasses. Minor amounts of other compounds may also be present. The gasses are concentrated at fumaroles and mixed in with volcanic lavas, pyroclastic flows, and tephra. Typically as the volcanic materials travel down the mountain they lose much of their gasses and thereby decreasing the risks associated with these gasses.

Gases are hazardous because they can directly poison people and livestock as well as contaminate food stocks, and water supplies. Acidic gases can irritate lungs and eyes and corrode metal objects. Emanations of heavy gasses, such as carbon dioxide, can pond in low-lying depressions and suffocate people or animals.

Debris Flows

Debris flows or mud flows occur very frequently at Mt. Shasta volcano. These flows consist of a water saturated slurry of mud, sand, and rocks, up to many feet diameter. They resemble flowing concrete and generally follow stream channels on the mountain, but spread out on the lower, gentle slopes. They generally travel at 10-20 miles per hour but on steep slopes can accelerate to 50 miles per hour.

Mt. Shasta debris flows have been generated during volcanic eruptions as well as during times of volcanic quiescence. Melting glacial ice provides a great deal of runoff that mixes with loose rock debris and produces frequent debris flows on the north, east, and southeastern part of the volcano. It has been estimated that glacial meltwaters produce about four large, potentially

destructive debris flows every hundred years (Osterkamp and others, 1986). Debris flows can also be produced during volcanic activity when hot volcanic debris mixes with and melts snow or ice.

Fortunately, the city of Mt. Shasta lies on the southwest side of the volcano and is not affected by glacial melt waters. However, during a volcanic eruption, snowfields can be overrun by a pyroclastic flow or tephra and provide ample meltwater to form a debris flow. Cascade Gulch and Avalanche Gulch provide ready pathways to direct debris flows toward the towns of Mt. Shasta (Figure 8). Very large debris flows could enter the Sacramento River and travel to Dunsmuir and beyond.

Debris flows destroy by smashing with the large rocks that they carry and by burying large areas under debris. These slurries of debris and water are so dense that they can carry away many large and heavy objects, such as buildings, vehicles, and bridges. Debris flows could cover Highway 5, 97, and 89, disrupting all road traffic in or out of the area.

Debris flows can be produced at any time during an eruption episode. Worldwide, during historic times, debris flows are second only to pyroclastic flows in the number of casualties produced by a volcanic product (Tilling, 1989).

Landslides

Steep composite volcanoes, such as Mt. Shasta, are subject to occasional, massive slope failures. These landslides can occur without any associated eruptive activity but are more likely to occur during an eruption, especially where the intruding magma greatly expands the volcano or one that produces violent seismic shaking. The landslides can be enormous and remove entire portions of the mountain.

A large debris avalanche occurred 300,000 to 380,000 years ago at the Mt. Shasta volcano which filled the Shasta Valley between Black Butte and Yreka with 17 cubic miles of debris. This deposit covers 260 square miles with an average depth of 218 feet. There is no evidence that a volcanic eruption occurred with this prehistoric landslide (Crandell, 1989).

Crandell (1989) estimated the runout along several of the surrounding river channels in the event of a landslide of at least 0.389 cubic miles (1 cubic kilometer) occurred (Figure 9). The area inundated by such a deposit will probably include a wide swath on either side of these channels. There is no way to predict such a landslide.

CONCLUSIONS AND RECOMMENDATIONS

The Mt. Shasta volcano has a long but irregular record of eruption, with its most recent activity occurring only about 200 years ago. Fumarolic and hot spring activity persist at the summit area which suggests that there may still be a body of molten rock below the surface. The recent eruptive record indicates that Mt. Shasta volcano will erupt again at a time and with a magnitude that are not possible to predict.

The included maps and foregoing discussion outlines the types of hazards that could affect the city of Mt. Shasta and its sphere of influence. Phenomena such as major inundating landslides and enormous lateral blasts are nearly impossible to plan for however the chances of one occurring are remote. Early planning and development of contingency plans in cooperation with local, State, and federal governments is the first step to planning for a potential volcanic eruption. A communication system and plan is an essential ingredient of this.

Evaluation of existing infrastructure systems such as power, telephone, water, sewer, and other utilities; roads, and landing strips for their location and resistance to the effects of various volcanic hazards should be accomplished.

Long term planning and zoning should discourage the building of critical structures in the most hazardous areas in order to avoid volcanic hazards. Flowage hazards, such as pyroclastic flows, debris flows, and lavas will require thoughtful zoning to mitigate possible damages and loss of life. Low-lying areas should be avoided.

The city of Mt. Shasta lies in the lower portion of a broad pyroclastic and debris fan on the southwest side of the volcano. Cold Creek, Big Springs Creek, and Wagon Creek run along the base of the fan and are a likely "gutters" into which any far-traveled flow would empty. The lower portions of the drainages of Cascade Gulch and Avalanche Gulch are ready pathways for flows to travel into the city of Mt. Shasta. Additionally, the city should not plan on building in these two drainages (Figure 10).

Hazards due to volcanic airfall and earthquakes (both tectonic and volcanic) can be reduced by requiring building foundations, walls, and roofs to be properly supported and kept in good repair. Proper geotechnical examinations should assure that foundations are set in well consolidated deposits or hard rock.

Development should be avoided in poorly consolidated substrates, especially those with high water tables, such as marshes, meadows, as well as active river and stream flood plains. Building on the shore of any body of water, such as a lake, should be avoided.

Steeply-gabled roofs designed for snow should also be effective for

shedding volcanic ash. Flatter-topped buildings should have easy access to the roof and handy shovels to remove collapse causing debris.

Education of the citizenry including distribution of pamphlets on the possible volcanic hazards (such as Crandell and Nichols, 1987) should be done along with development and distribution of the long term planning goals and emergency contingency plans for the community.

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Figure 1 City of Mt. Shasta. General Plan - Sphere of Influence

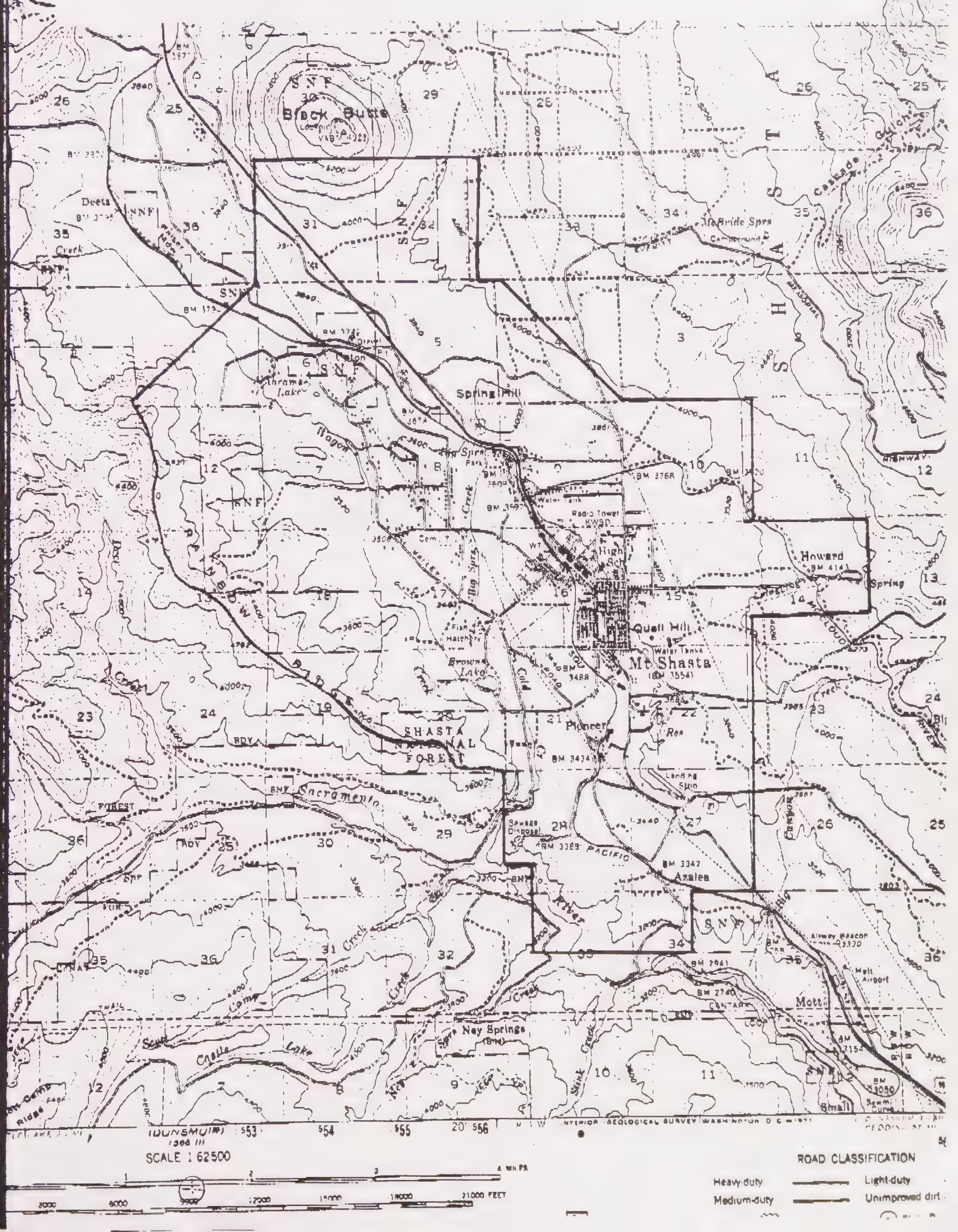
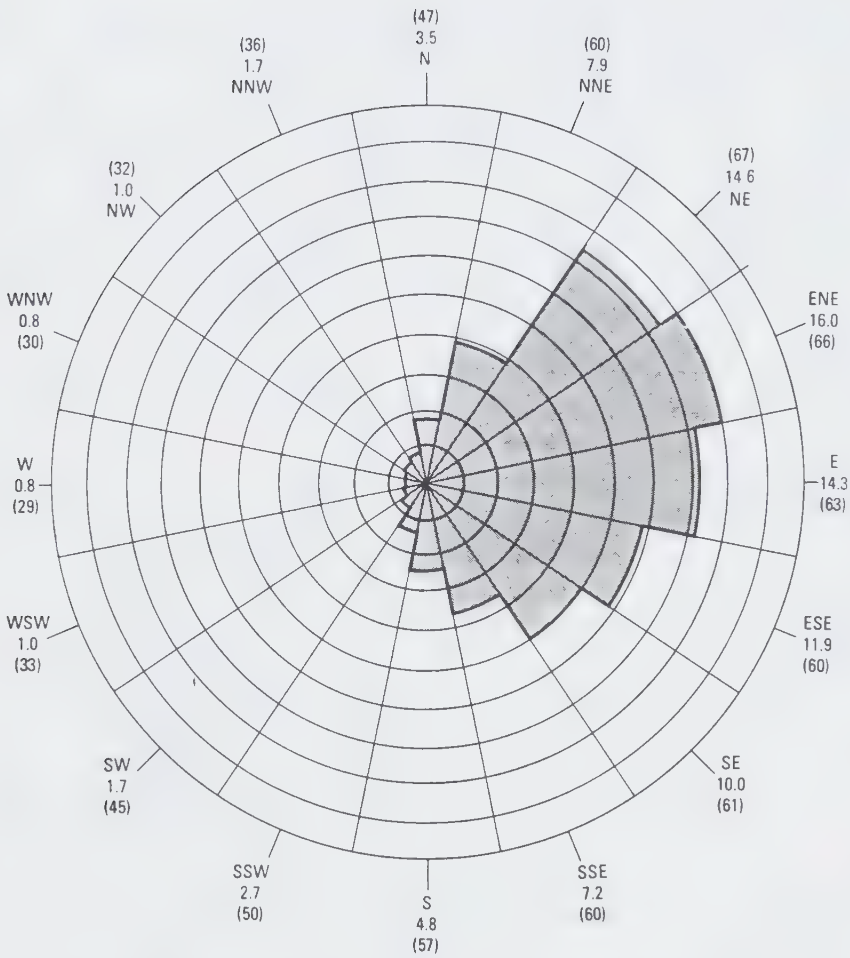


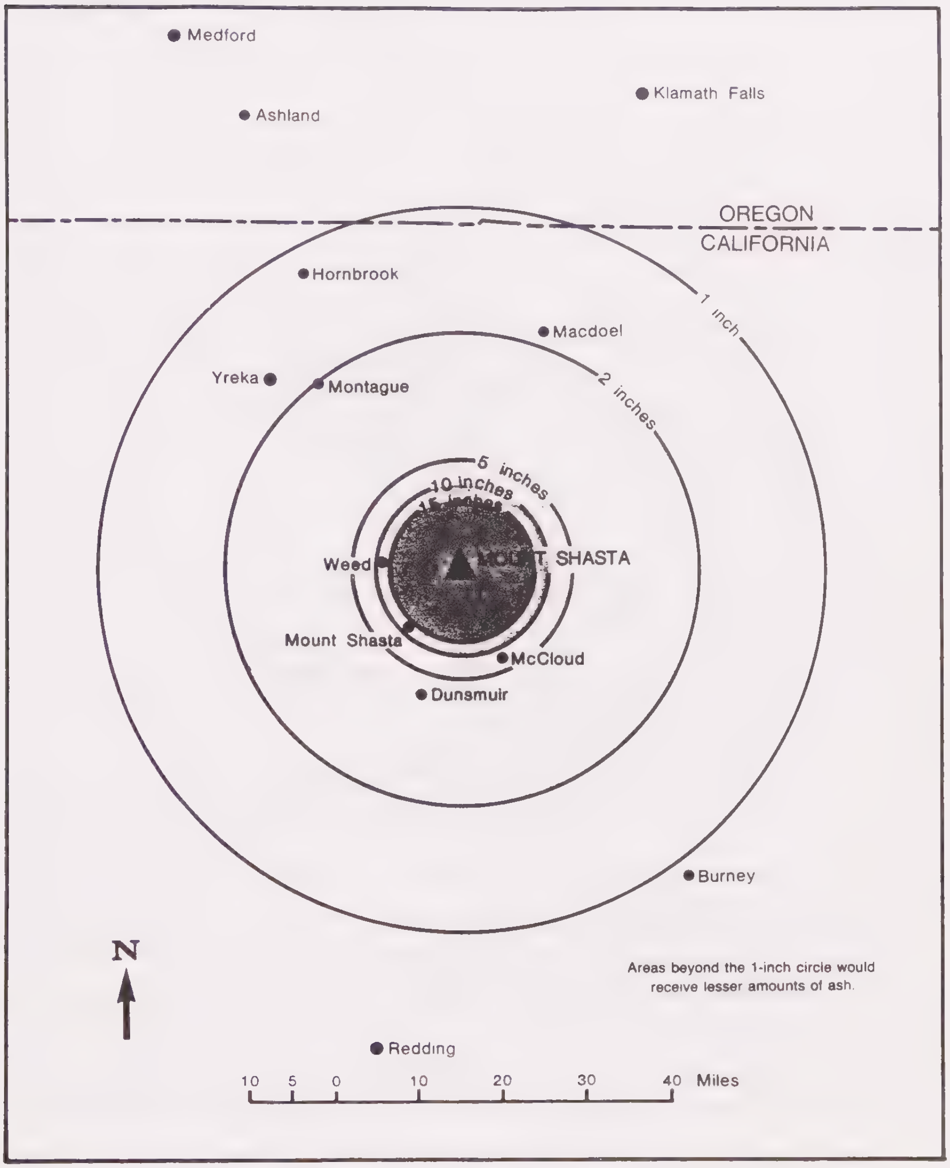
Figure 2



Percentage of time annually that the winds at elevations between 3000 and 16000 m blow toward wedge-shaped sectors along principal compass directions over Medford in southern Oregon (indicated by stippled pattern). Average wind speeds in kilometers per hour (rounded off to the nearest whole number) for winds blowing in each direction are shown in parentheses. Directions and speeds are averaged from 21-year records at Medford, Oreg. (Winds Aloft Summary of the Air Weather Service, U.S. Air Force, available from the National Climatic Center, Asheville, N.C.)

(Miller, 1980)

Figure 3

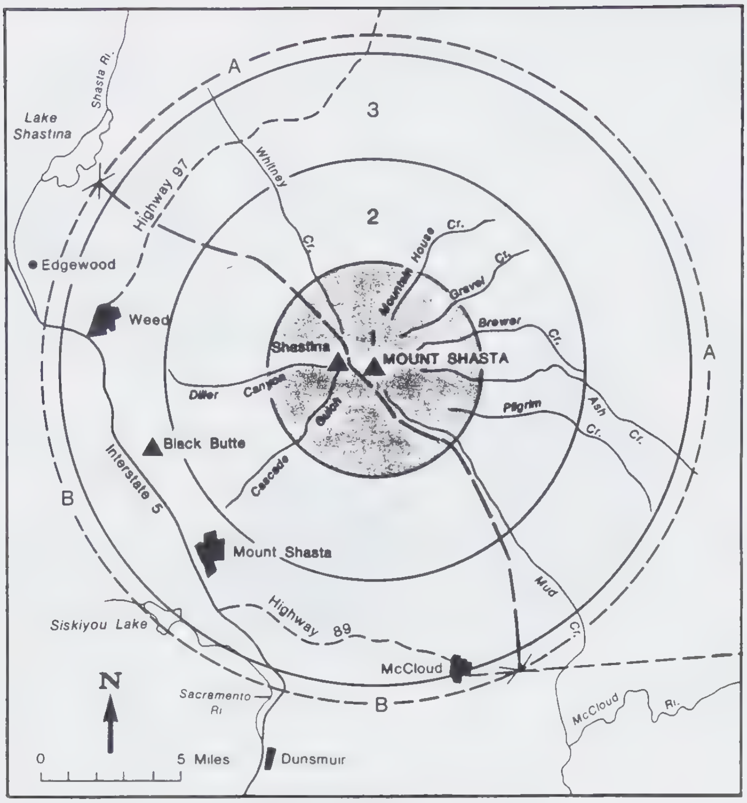


Volcanic-Ash Hazard Area Map

Thicknesses at various distances are based on the largest ash eruption of the last 10,000 years at Mount Shasta. Because of prevailing wind directions, ash most likely will fall somewhere east of a north-south line through the center of the volcano.

(Crandell and Nichols, 1987)

Figure 4



Lava Flow Hazard Zones Map

Circular numbered zones show possible hazard from lava flows with respect to distance from the top of the volcano.

Zone 1—areas likely to be affected most frequently.

Zone 2—areas likely to be affected by lava flows erupted at flank vents or that move into zone 2 from zone 1.

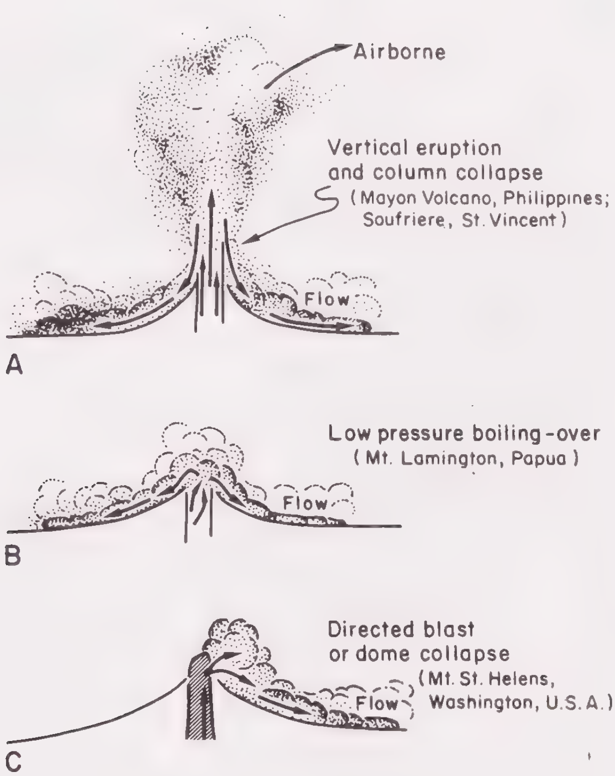
Zone 3—areas likely to be affected infrequently and then only by long lava flows that originate at vents in zones 1 and 2.

Lettered sectors show possible hazard from lava flows with respect to areas in which they are likely to occur. Lava flows are most likely in sector A, and less likely in sector B.

(Crandell and Nichols, 1987)

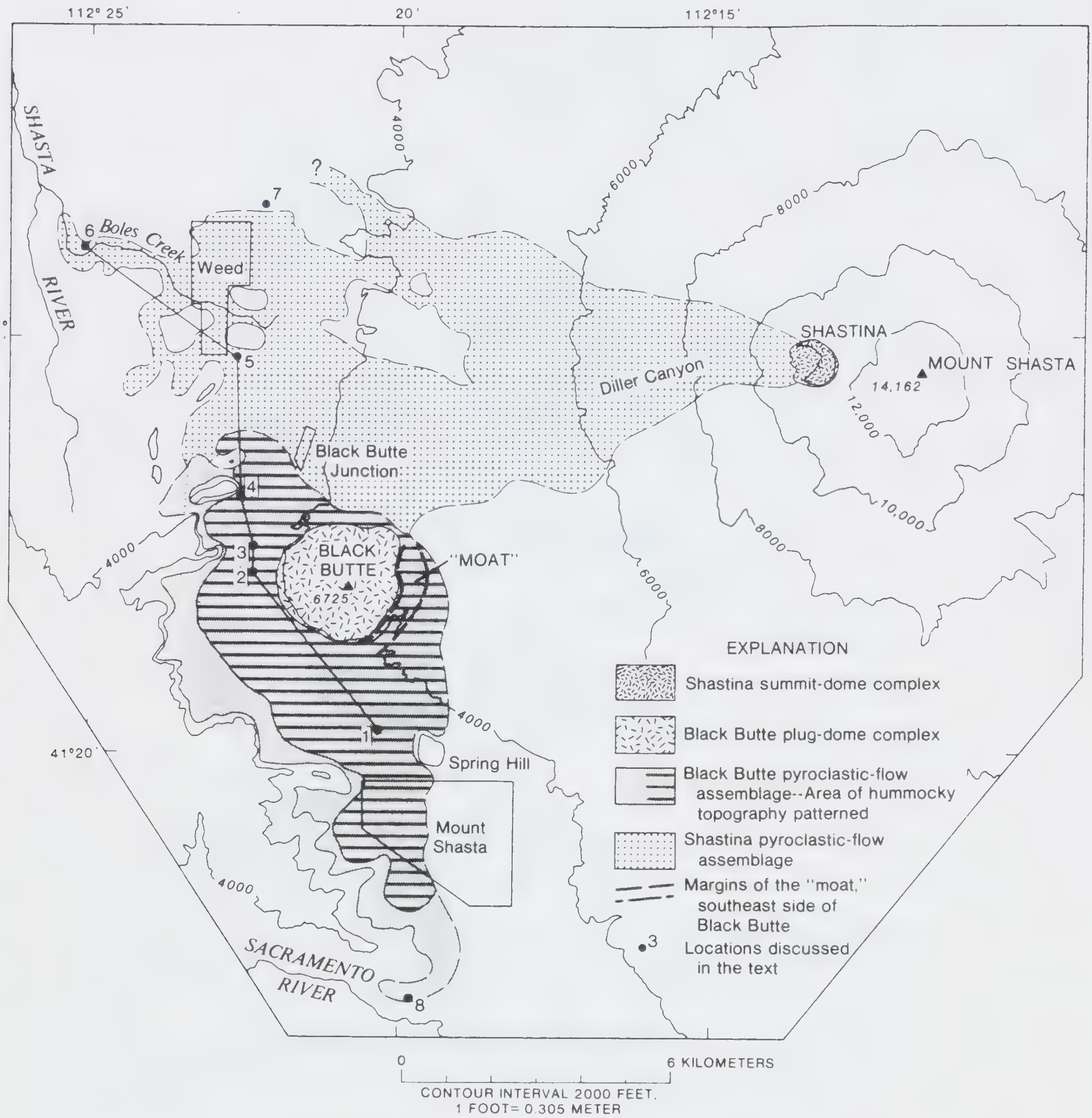
Figure 5

Some ways that pyroclastic flows can originate.



(Fisher and Schmincke, 1984)

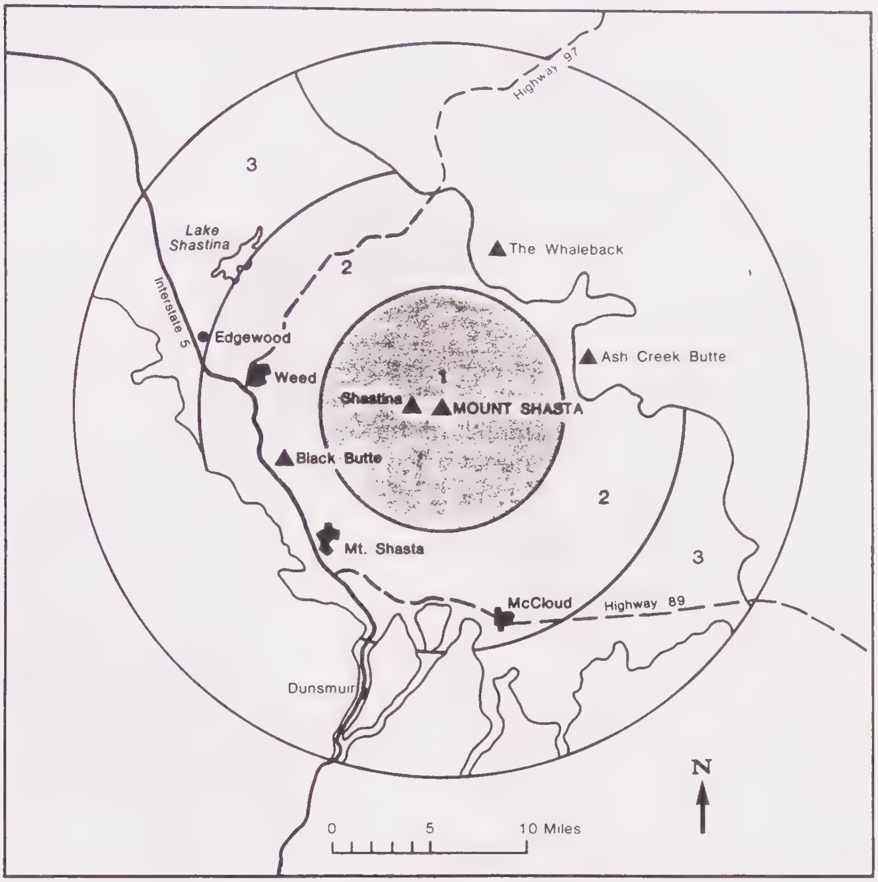
Figure 6



Map of pyroclastic-flow assemblages from Black Butte and Shastina. Outlines dashed or queried where extent uncertain. Base modified from U.S. Geological Survey 1:62 500, Weed, Shasta, 1954.

(Miller, 1978)

Figure 7

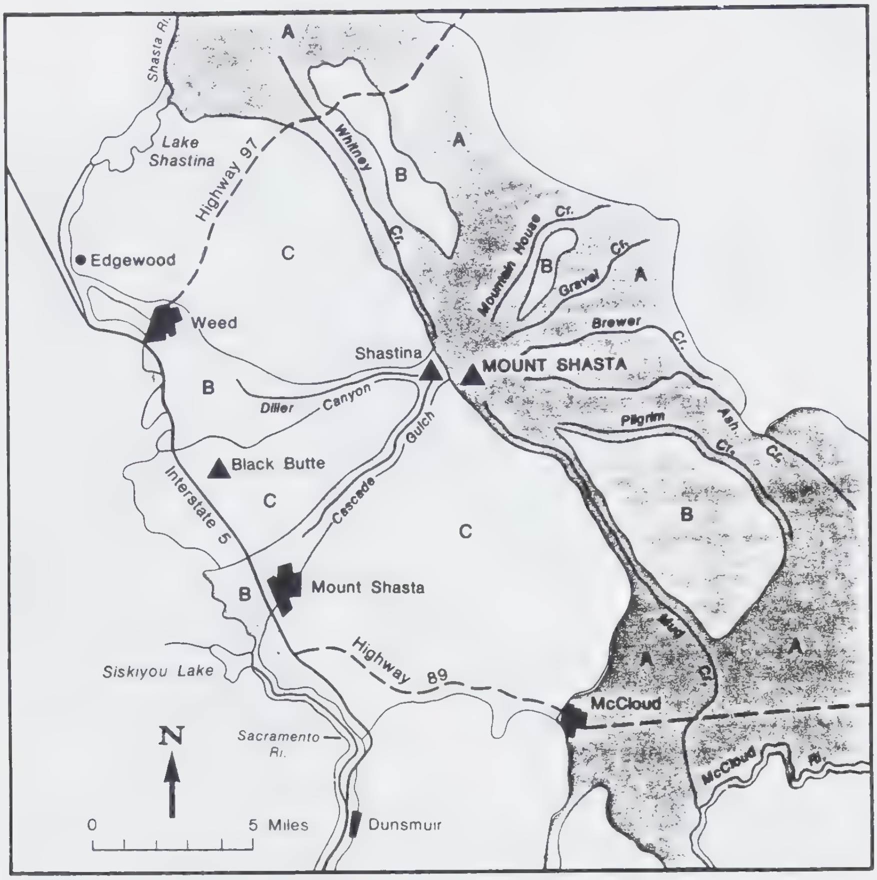


Pyroclastic Flow and Lateral Blast Hazard Zones Map

Zone 1—Areas likely to be affected most frequently by future pyroclastic flows and associated ash clouds.
Zone 2—Areas likely to be affected less frequently by future pyroclastic flows and associated ash clouds.
Zone 3—Areas likely to be affected mostly by ash clouds associated with pyroclastic flows in zones 1 and 2, but could also be affected by very large but infrequent pyroclastic flows.
A lateral blast could affect any area within the outermost circle, but the likelihood of an area being affected decreases with increasing distance from the volcano. The boundaries of zones 1, 2, and 3 are irregular because they are located at the base of hills or mountains.

(Crandell and Nichols, 1987)

Figure 8

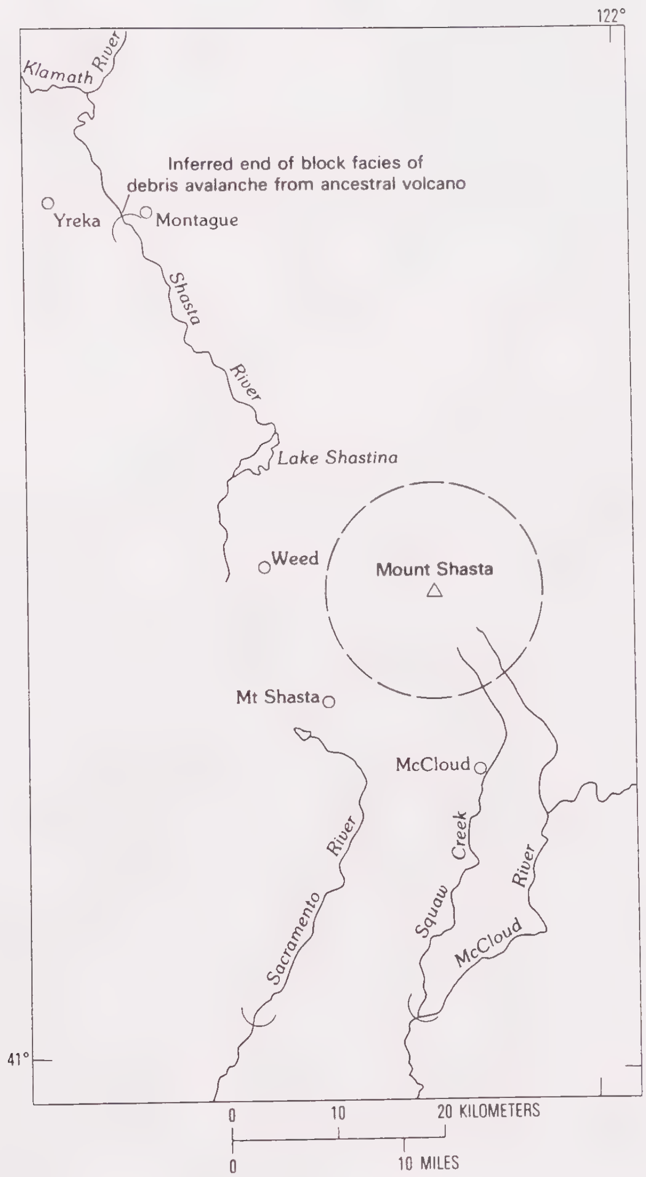


Mudflow Hazard Zones Map

Zones designated by letters show relative likelihood of being affected by future mudflows. Zone A is most likely and zone C is least likely to be affected. No mudflow hazard exists on high areas within or beyond the zones. Hazard decreases everywhere within the zones with greater height above stream channels and greater distance from Mount Shasta.

(Crandell and Nichols, 1987)

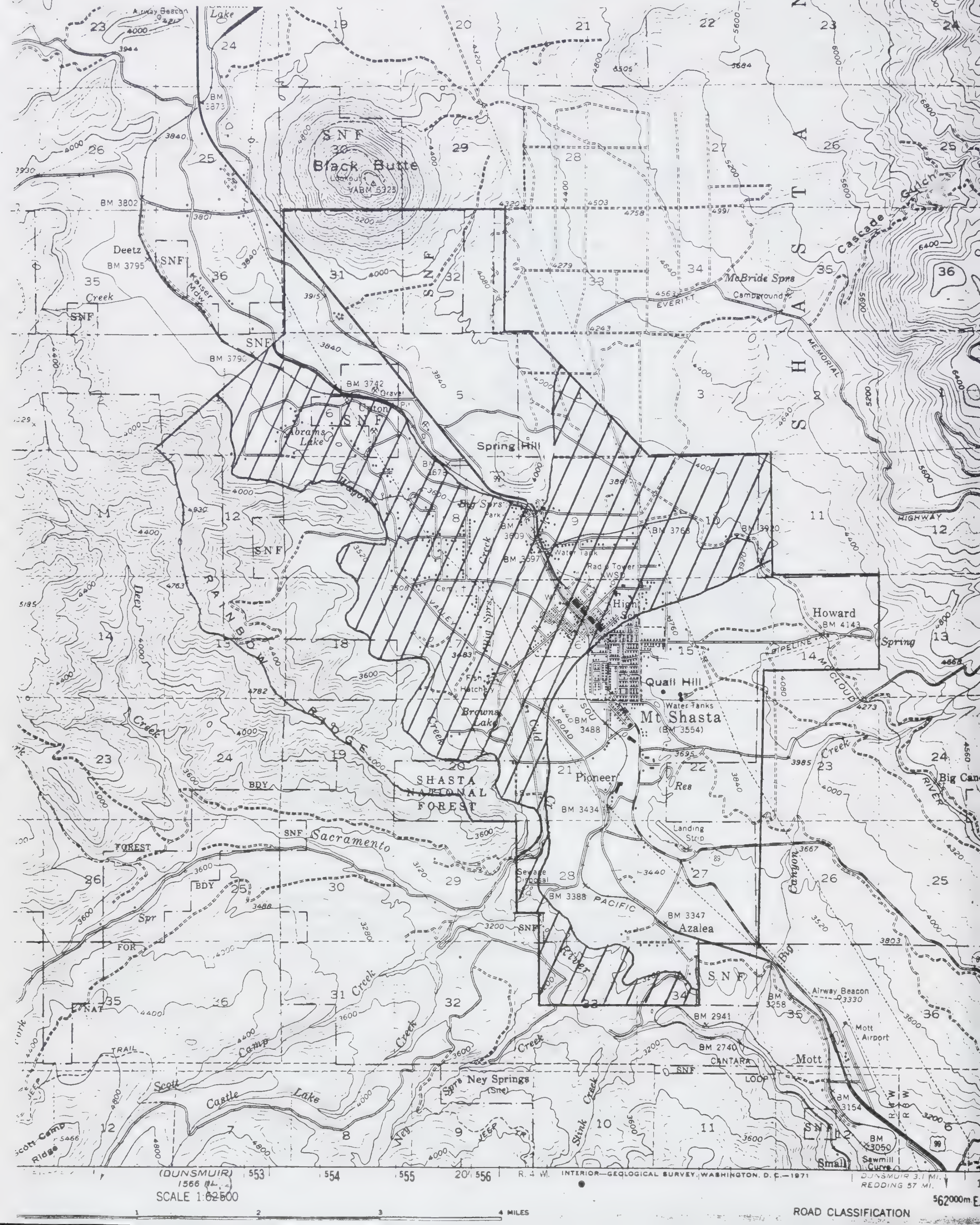
Figure 9



Map of Mount Shasta volcano and adjacent area. Semicircles show the distal ends of possible future debris avalanches, which have volumes of at least 1 km^3, in three valleys heading on the volcano.

(Crandell, 1989)

Figure 10 Generally low lying area to target for minimal development. This will lower general risk from volcanic flowage features.



MT. SHASTA SPHERE OF INFLUENCE